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MEASUREMENT IN SCIENCE FOR BLIND STUDENTS

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Blind students have difficulty in learning measurement concepts in science because of their inability to read standard measurement devices. This problem prompted the study, Measurement in Science for Blind Students (Franks, 1969). The study was conducted at the Instructional Materials Reference Center for Visually Handicapped Children, American Printing House for the Blind. A systematic effort was made to discover and evaluate science materials currently available for use by the sighted and to adapt these where possible for the instruction of blind students. New devices were to be developed when necessary. The preliminary examination suggested that a number of basic measurement concepts could be illustrated using a small number of devices. Four such devices were developed in the study and tested with a group of elementary and junior high blind students.

Analysis Pinpoints Major Concepts and Instruments to Illustrate Each

Several sets of seventh, eighth and ninth grade science textbooks, in inkprint and braille, were examined to identify the basic measurement concepts presented and the instruments used to illustrate them. These sets included appropriate volumes from the following series which have been transcribed into braille by the American Printing House for the Blind:

Science Today and Tomorrow Series. Craig, et al. Ginn, 1958.

Harcourt, Brace and World Science Program. Brandwein, et al. Harcourt, Brace and World, Inc., 1964.

Today's Basic Science Series. Navarra and Zafforoni. Harper and Row, 1965.

Van Nostrand Science Series. D. Van Nostrand Co., 1965, 1966.

The basic measurement concepts were categorized into three areas: life science, earth science and physical science. It was found that there is considerable overlap in concepts taught throughout the grades. Basic measurement operations and concepts identified in the study and the devices used to illustrate them are presented in Table 1.

Table 1

Measurement Concepts and Devices

Measurement Concepts		Measurement Devices
1. Linear measurement (metric and English system)	-	Ruler
2. Nature of energy and matter	-	Thermometer, Balances, Weights, Graduates, Blocks of equal volumes with different weights
3. Composition and general properties of matter	-	Balances, Weights, Graduates, Thermometer
4. Meaning of volume and weight	-	Balances, Weights, Graduates, Blocks of equal volumes with different weights
5. States of matter	-	Thermometer
6. Changes in temperature	-	Thermometer
7. Mass and inertia	-	Balances, Weights, Blocks of equal volumes with different weights

The measurement devices are those which appeared most frequently in the textbooks. The complete list of devices required to demonstrate these basic concepts includes:

1. Thermometer
2. Ruler in inches and centimeters
3. Balances, spring and platform

4. Weights
5. Graduates and other measurement containers
6. Blocks of equal volumes with different weights

Examination of various specialized and commercial catalogs indicated that most of these measurement instruments were available commercially. It appeared that with adaptation the instruments could be used effectively by blind children.

Four of these devices: the ruler, spring balance, pan balance, and thermometer were adapted so that blind students could read them. The ruler was adapted by adding raised lines to indicate centimeters and inches. A dial spring balance was adapted by adding raised lines to the face to indicate weight measurements. Different textures on the face were used to differentiate the gram scale from the ounce scale. A raised vertical line was added to the face of the pan balance to indicate the center of the face. The dial thermometer was adapted by adding raised lines around the outer edge of the face. The two other instruments essential to performing the basic measurement operations were the overflow can and the catch can which required no special adaptations.

Research Utilized in Modification of Measurement Instruments

Modification based on tactile needs. While a survey of the literature yielded little specific research in measurement in science, a number of related studies did report findings relevant to modifications of the instruments.

Schiff (1966) states that contrast is the most important principle for construction of raised-line diagrams and that simplicity is possibly the second most important. For the construction of the ruler, emphasis has

been on simplicity of design to keep down "tactile noise." Schiff, Kaufer and Mosak (1966) suggested that if a tactile array is fairly simple, there may not be a gain in using special symbols.

Nolan and Morris (1963; 1965) found in studies of types of sandpaper used in the Roughness Discrimination Test that 60 grit was identified by 140 kindergarten through fourth grade subjects with only 6.4% errors. Schiff (1966) found four grades of standard sandpaper readily discriminated by high school and college students. These grades of sandpaper, although discriminable when reproduced on Brailon in areas as small as 3/4 inches square, were less coarse than 60 grit sandpaper. Therefore, a 40 grit sandpaper was selected for the face of the inner dial of the spring balance to increase contrast and to overcome additional "noise" on the surface area.

Gibson (1962; 1966) notes the importance of distinctive tactile edges of some objects. Schiff (1966) considers the height of a tactile edge an excellent way of providing discriminable differences in area coding. Tactile edges were incorporated where applicable in modifying the measurement devices.

The distance between lines is also an important consideration in constructing tactile arrays. Wexler (1963) has stated that the eye can locate a point to within a distance of 0.625 mm. The finger requires a space four times that great. Schiff and Isikow (1966) found that a difference of two milimeters between histograms was barely adequate and actually too small for efficient interpretation. Differences of more than 10% or more than two milimeters are desired for easily discriminable diagrams. All spaces between lines in the instruments adapted exceeded 10% or six milimeters minimum.

A minimum rise of .025 inches was accepted for height of lines used. Morris and Nolan (1963; 1967) found that seven linear symbols with an average relief of .022 inches as used in press-made braille books met stringent criteria for discriminability.

Where feasible, these findings were implemented in development of special tactile faces for the instruments. Efforts were made to adapt instruments according to the tactile needs of the blind student rather than translating per se visual symbols to tactile symbols.

Modification of instruments. Adaptations were kept as simple as possible. Less sophisticated devices are required to illustrate and explain the basic measurement concepts identified in the textbook analysis than would be required to perform more advanced precision measurement operations.

Measurement Instruments Adapted or Developed for Blind Students

Following is a brief description of the four measurement devices adapted and/or developed.

1) The ruler. The ruler was developed to teach the difference between the metric and English system, and for general measurement operations. Teaching the difference between the metric and the English system is facilitated by originating the centimeter scale at the upper corner and the inch scale at the lower corner with measurements progressing from left to right. With this arrangement it is simple to illustrate that two and one-half centimeters are equal to one inch approximately. To assure accurate reading of notations, no dimension smaller than one-half centimeter nor smaller than one-quarter inch appears on the ruler.

The raised line indicators are approximately .025 inches in height. Braille notations occur at two centimeter intervals beginning with the second interval. Inch intervals are also labeled. The ruler is 1 1/2 inches wide, and one-fourth inch thick in the center tapering down to one-eighth inch at the reading edges. The back of the ruler is hollow to provide flexibility and to reduce weight.

2) The (dial) spring balance. The dial face for the spring balance consists of a complex radial display of raised lines and surfaces designating grams (in tens-of-grams) along the outer perimeter and ounces countersunk within an inner circle. Grams are indicated in 25 ounce raised line units along the perimeter with braille notations at every other 25 ounce designation. The raised lines are approximately .040 inches high. Distance between lines is more than 6 milimeters.

To overcome possible confusion caused by the shift from grams indicated along the outer perimeter to ounces indicated on the inner dial, contrast of the two sets of units is emphasized by the use of textures. The outer dial consists of a smooth surface and the inner dial is a rough, textured surface. The inner dial is countersunk approximately .050 inches to provide a distinctive tactile edge. This redundancy was built in as an aid to perceptual performance because of the complexity and high noise level of the tactile face of the spring balance. Schiff and Isikow (1966) stated that as diagram difficulty increases, additional redundancy appears to play a role in reducing errors. Redundancy involves encoding a message so that it contains more symbols or stimulus features than the minimum necessary to

transmit the information contained in the message. The authors concluded that the best mode of presentation in diagrams when "noise" is high is the textured and raised format--the most redundant. Thus contrast and redundancy are emphasized in the adaptation of the face of the spring balance.

This spring balance is designed for weighing in grams, although weighing in ounces can be accomplished. The balance is so designed that the index finger can be used to find measurements indicated by the needle, usually in grams. Then the middle finger can be used as an anchor while the index finger moves from the gram scale across the tactile boundary to the ounce indicators on the textured inner dial. The ring finger can be employed, if necessary, for holding the original starting point as the index finger moves to the inner dial and the middle finger follows over the tactile edge between the two dials.

3) The pan balance. The face of the pan balance is less complex than that of the spring balance. An object of unknown weight is placed in the left tray and balanced with known weights in the right tray. The face of the pan balance consists of a smooth surface with a wide, raised vertical line to mark its center. When the needle rests on the raised center line, the pans are in balance. If the needle is "off center", then weight must be added to or subtracted from the right hand tray to achieve balance.

4) The Fahrenheit (dial) thermometer. The face of the dial thermometer is three inches in diameter. Around the outer edge approximately one-fourth inch above the base is the tactual portion of the face. Temperature is indicated in ten degree units by one-fourth inch lines that are approximately .040 inches high.

Both freezing point (32°F) and boiling point (212°F) are marked with a large braille dot some .050 inches high. The interval from 70 to 80 degrees Fahrenheit is indicated by a rough textured surface raised to approximately .040 inches. Zero degrees Fahrenheit is indicated by a notched incision in the outer rim of the dial face.

The thermometer is designed to indicate temperatures ranging from below freezing to boiling point, with emphasis on indicating points at which phase changes in matter occur. Although the thermometer was not designed for general use, it can be used to perform a number of activities in measuring temperature. The textured ten degree interval between 70 and 80 degrees enables students to measure temperatures of liquids at room temperature more easily and serves as a reference point between freezing and boiling points.

Evaluation of Blind Students' Use of Measurement Instruments

Curriculum analysis of junior high science content provided the basic measurement concepts which the devices were to illustrate. With measurement operations identified and measurement instruments adapted, the next step was the evaluation of the instruments. The evaluation project is summarized below:

Purpose. To determine if blind students at the elementary and junior high level can successfully perform tasks in measurement which indicate their ability to read the tactile faces and raised surfaces on the measurement devices.

Subjects. Seventy subjects, 51 junior high and 19 elementary school students, grades four through nine, were used to field test the instruments. Distribution of students by grade is given in Table 2.

Table 2

Distribution of Students

	Grade	Number of Students
Junior High:	9th	10
	8th	23
	7th	18
	Grade	**Number of Students**
Elementary	6th	13
	5th	4
	4th	2

All students were braille readers from residential schools for blind children.

Summary of Results

On the four devices, 86% of the assigned measurement tasks were successfully completed. A breakdown of percentages for individual devices is presented in Table 3.

Table 3

Mean Performance Scores

Ruler	Spring Balance	Pan Balance	Thermometer
79%	86%	80%	99%

The high level of performance achieved by both groups on the test indicates that both elementary and junior high students can read the tactile table faces on the instruments well enough to perform elementary measurement operations.

Concepts Taught Using Specially Adapted or Developed Instruments

Basic concepts and generalizations in measurement in science which can be taught using these devices follow. The purpose of each instrument is stated.

The Ruler. This instrument allows blind students to perform linear measurement operations. The ruler is marked in inches and centimeters and can be used as an aid in teaching the difference between the metric and the English systems of measurement.

The (Dial) Spring Balance. This instrument measures weights in grams and ounces. It can be used to measure approximate weights, to teach conversion of grams to ounces, and to teach the concept of gravity.

The Pan Balance. This instrument measures weight in grams. It teaches the use of the pan balance when more accurate measurements than those afforded by the spring balance are required. It can be used to to teach the following concepts and generalizations:

If an object is placed on the left pan and is balanced by the weights on the right, the earth's gravitational force is the same for both--the two forces are the same for each pan.

The Fahrenheit (Dial) Thermometer. This instrument enables blind students to measure changes in water temperatures from freezing to boiling point. It also allows them to tactually observe changes in temperature that occur during phase changes in matter.

It can be used to teach the following concepts and generalizations:

1. Water exists in the environment in all three states of matter: solid (ice), liquid (water), and gas (water vapor). Whenever one state changes into another, heat is gained or lost. These changes in heat can be measured.

2. Condensation (dew) may form on anything that has a temperature which is lower than the dew point of the air that touches it, if the temperature at which condensation is taking place is above 32°.

3. When ice is placed in water, temperature of the water decreases until it approaches freezing temperature (32°).

4. Evaporation is a cooling process during which temperature decreases.

5. Frost will form if the temperature at condensation is below 32°.

6. When heat is removed from water, it gets steadily colder until it reaches 32°. The water stays constant at this temperature until all of it is frozen. Then its temperature begins to drop again if more heat is removed.

7. When salt is mixed with ice in a container the temperature of the mixture drops low enough to cause an inserted test tube partially filled with water to freeze solid, although the mixture itself becomes less solid.

The Overflow Can and Catch Can. These instruments are used to measure volume in fluid ounces. They can be used to teach the determination of volume of small irregular objects by liquid displacement. They also illustrate density and gravity.

The instruments can be used to teach the following concepts and generalizations:

1. Two objects cannot take up the same space at the same time.

2. The apparent loss of weight of an object placed in a container of water is equal to the weight of the liquid displaced.

3. Specific gravity is the weight of an object divided by the weight of an equal volume of water. It is the ratio of a solid or liquid to the density of water.

4. If the density of an object is greater than that of water, the object sinks.

5. If the density of an object is less than that of water, the object floats.

6. Fluids push up on objects immersed in them. Buoyancy is the name given to this force.

Measurement in Science Kit. A Measurement in Science Kit (Cat. no. 1-0364. $97.50) which includes the devices described above has been completed and is available from the American Printing House for the Blind, Louisville, Kentucky, (See Figure 2).

The Kit contains:

1) A ruler, in inches and centimeters
2) A (dial) spring balance, in grams and ounces
3) A pan balance, in grams
4) A Fahrenheit (dial) thermometer
5) A set of gram weights
6) An overflow can and a catch can
7) Blocks of equal volumes with different weights
8) Specific gravity weights
9) An electric hot water heater

Two copies of the activities and experiments which may be used to illustrate the concepts and generalizations outlined herein are included in the kit. One is in braille, the other in large print.

Summary. The Measurement in Science study (Franks, 1969), identified instruments necessary to teach students scientific measurement operations and basic properties of matter. Based on an analysis of

science textbooks, the instruments essential to te ching most of the basic measurement concepts taught in elementary and junior high school were chosen. These instruments were then adapted for use by blind students.

It is hoped that this article will encourage teachers to allow their blind students more participation in laboratory type experiments in science. In the study 86% of the measurements and simple experiments tested were successfully performed. With the addition of tactile surfaces allowing students to read dials with their fingers, the students gained a better understanding of the properties of matter by actually making measurements of length, width, volume, weight, and temperature. At the same time they were able to observe changes in the states of matter which accompanied changes in measurements they made. They gained a greater understanding of phenomena such as condensation, gravity, and density which are difficult to understand without the benefit of demonstration.

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